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RESEARCH ARTICLE

EFFECT OF DIFFERENT NITROGEN DOSE ON GROWTH AND YIELD CHARACTERESTICS OF HYBRID MAIZE (*Zea mays* L.) VARIETIES AT SUNDARBAZAR, LAMJUNG

Bhimsen Mahat[a], Bijaya Upadhayay*[b], Ajay Poudel[b]

[a]Institute of Agriculture and Animal Science, Lamjung, Nepal
[b]Agriculture and Forestry University, Rampur, Chitwan, Nepal
**Corresponding Author Email:bijusharma616@gmail.com*

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ABSTRACT

This research aimed to determine the best combination of nitrogen levels and hybrid varieties for optimal growth and yield of hybrid maize in Sundar bazar municipality, Lamjung, Nepal. The study used a two-factor factorial randomized complete block design (RCBD) with 12 treatments and three replications. The treatments consisted of two hybrid maize varieties (Rampur Hybrid-10 and CP 808) and six different levels of nitrogen doses (control, 120, 150, 180, 210, 240 kg N ha-1). The results showed that the growth and yield parameters of hybrid maize varieties increased significantly with increasing nitrogen levels. The application of nitrogen at the rate of 240 kg N ha-1 produced the highest plant height, number of leaves, leaf area index (LAI), stem diameter, thousand grain test weight, grain per cob, grain yield, biological yield, and harvest index. Even a small difference of 30 kg of nitrogen ha-1 within a treatment showed a significant effect on the growth and yield parameters of hybrid maize. The control plot had the least growth and yield parameters. The hybrid maize variety CP 808 outperformed Rampur Hybrid-10 in terms of grain yield, thousand grain test weight, cob length, grain per cob, and LAI. In conclusion, this study suggests that cultivating hybrid maize variety CP-808 with the use of nitrogen at the rate of 240 kg ha-1 is optimal for maize production in Sundar bazar, Lamjung, and mid-hills of Nepal with similar altitude and climatic conditions. This information can assist maize farmers in achieving high yields and increasing their income.

KEYWORDS

Growth, Yield, Hybrid, Maize, Nitrogen use efficiency

1. INTRODUCTION

1.1 Background

Maize is a major cereal crop that plays a significant role in the global agricultural economy as both food for humans and feed for animals. Maize is a versatile crop that is commonly cultivated for various purposes such as food, feed, and fodder. This crop is known for its nutritional value as it comprises around 72% starch, 10% protein, 9.5% fiber, and 4% fat, and is highly nourishing with an energy density of 365 Kcal per 100 grams further known as "Queen of the Cereals" (Begam et al., 2018; Nuss and Tanumihardjo, 2010). It is the second most important cereal crop after rice in Nepal and is grown in 979,776 hectares of land with an average production of 2,997,733 tons and productivity of 3.06 tonha^{-1} (MoALD,2021/22). Maize occupies about 31.69 % of the total cultivated agricultural land and shares about 28.27 % of the total cereal production in Nepal. It shares about 4.63% to Agricultural Gross Domestic Product (MOALD, 2078). Most of the maize cultivating area (83.88%) lies in the mountains (10.36%) and Hills (73.52%) of Nepal, the productivity of the province-1 (3.0 ton ha^{-1}), Madhesh (3.48 ton ha^{-1}), Bagmati province (3.35 ton ha^{-1}), Gandaki province (3.02 ton ha^{-1}), Lumbini (2.86 ton ha^{-1}), Karnali (2.72 ton ha^{-1}) and Sudurpaschim province (2.71 ton ha^{-1}) (MoALD, 2078). In Lamjung, it is grown in 43,896 hectares of land with the productivity of 2.35 tonha^{-1} (MOALD, 2078).

Maize is summer (April-August) seasonal crop in Hills, grown as single crop or relayed with millet later in the season. In the Terai, inner-Terai, valleys, and low-lying river basin areas, it can be grown in the winter and spring with irrigation. Major portion of the maize produced in the mid Hills and high Hills is used for direct human consumption as staple food in household level. A significant proportion of maize production in Terai is directed towards the market, with less than 50% being utilized for human consumption. Maize is becoming increasingly significant as a commercial and industrial crop, with a variety of products being made from its grains.

The maize demand has grown at a rate of approximately 6% annually over the last decade and it is estimated that over the next two decades, the overall demand for maize will rise by 6-8% annually, primarily due to an increase in demand for food in Hill regions and feed (11% growth rate annually) in Terai and Inner Terai regions (Paudyal et al., 2001; Sapkota and Pokhrel, 2013). Over the past five years, the demand for poultry feed and animal feed in Nepal has risen by 13% and 8.5%, respectively (Timsina et al., 2016). According to a study, it was found that 60% of the grain was utilized as animal feed, 25% as food, and 3% as seed in the Terai region. The remaining portion of maize (12%) was sold to various buyers (Timsina et al., 2016). To fulfill the growing feed demand, Nepal is importing about 45% of maize from India (Neupane and Subedi, 2019).

To sustain the current poultry industry in Nepal, approximately 6.46 million metric tons of feed are required annually, compared to 0.5 million metric tons produced domestically. (NFEA,2021). With the shift in demand for maize from food to livestock and poultry feed, there is also a growing need for new maize-based products like soups, vegetables, and edible oils. To address the challenge of heavy import, it is necessary to increase the productivity of maize on limited available land.

The area, production and productivity of maize in Nepal have been increasing since 1984, but the production remains low compared to neighboring countries (MOALD, 2078). One of the reasons for this might be a stark difference between Nepalese maize varieties yield (5.49 tons h^{-1}) and national average yield (3.06 tons h^{-1}), creating a yield gap of 2.03 tons h^{-1} (MOALD, 2078)

Almost half of the maize cultivation area is planted with conventional varieties, i.e., home-saved seeds that are prone to degeneration due to open pollination, and there is a lack of sufficient application of manures and fertilizers (Bahadur BK and Shrestha, 2014). The maize production faces several challenges such as diminishing soil fertility, limited access to improved seeds and quality fertilizers, and the emergence of new pest species, all of which contribute to the low yield potential of existing genotypes. To enhance maize productivity, it is essential to cultivate new high-yielding varieties using optimal cultural practices and timely application of appropriate nutrients in the required amounts.

1.3 Statement of Problem

There is wide gap between farmer's field yield and research field. The productivity of maize is still very low (3.06 $tonha^{-1)}$ (MoALD, 2078). There is a need to improve the productivity of maize in order to maintain food balance in the country and for that Hybrid varieties can play an important role in increasing the present yield level.

Several factors contribute to low maize production in farmers' fields, including a lack of high-yielding varieties, low plant populations, and haphazard use of chemical fertilizers. Furthermore, in recent years, the increased use of high yielding crop varieties in intensive cropping systems has led to a substantially increased demand for nutrients. The genetic potential of hybrid varieties may not be fully realized through the supply of nutrients solely from FYM/compost but, the high cost of inorganic fertilizer dramatically limits its use by farmers (Chapagain and Gurung, 2010). Nitrogen is perhaps the most crucial nutrient for optimum crop yields and its inaccessibility is a burning problem in most of the maize growing areas of Nepal. Moreover, even the nitrogen that is accessible, is not used judicially by the farmers because there is no updated recommendation on the doses of fertilizer for high yielding hybrids, winter, spring and summer season, rainfed and irrigated maize.

It is common knowledge that both the over and under use of nitrogen lead to yield decline. In such a situation, optimum application of N fertilizer is necessary to achieve optimum productivity. And there are about 7 hybrid maize varieties cultivated in Sundar bazar, Lamjung, most of which are Indian hybrids. The recommended dose of nitrogen over Indian conditions may not be best fitted in Nepalese conditions and here is hardly any information about the dose and efficient hybrid varieties. So, it is necessary to access the performance of hybrid varieties in this climatic scenario with different nitrogen levels for higher yields.

Farmers often rely on their own technology or recommendations from agro-vets or seed companies, as there are no agronomic management technologies recommended by the government of Nepal or the National Maize Research Program. Some farmers use high amounts of fertilizers, pesticides, and closer spacing, but due to a lack of technical knowledge, they may apply fertilizers haphazardly and not in sufficient quantities. Without knowledge of the right time, dose, and amount of fertilizer to apply at each stage of hybrid growth, yields can be reduced. However, by intervening in prevailing practices with promising technologies, yield levels in the Terai and mid-hills regions can be increased.

The general recommendation of 120 kg/ha of nitrogen may not be optimal for all hybrids or seasons, and different hybrids may have different optimal levels of nitrogen. Consequently, inappropriate selection of maize varieties, poor management of nutrients, damage from pests and diseases, and weed infestations become major factors contributing to low maize yields in Nepal (Chapagain and Gurung, 2010).

While some hybrids have been developed by the national research system of Nepal, hybrids from multinational seed companies are gaining popularity among farmers. This is because national hybrids are often unable to compete with multinational hybrids in terms of yield (Tripathi et al., 2016).

Another glaring problem is lack of quality assessment of the few domestically developed hybrids in the desired locations. Most maize varieties are only put under trial at research stations, which may or may not be representative of the field condition of a normal farmer. As a result, some released varieties have failed to meet farmers' production expectations, leading to a preference for multinational varieties over locally released ones. To address this issue, a study was conducted to evaluate 117 maize hybrids from 20 seed companies at three locations in Nepal. The study aimed to identify the best maize hybrids for planting during winter in these regions. But the study is only among the few that have been conducted successfully. There is a need of many of these types of similar research studies done throughout the nooks and corners of this geographically diverse country. This study is an attempt to do the same in the climatic conditions of Sundar bazar, Lamjung.

1.4 Role of Nitrogen Fertilizer Use Efficiency (NUE) on Maize Crop

Nitrogen fertilizer plays a crucial role in crop yield, contributing to about 50% of yield performance (Bakht et al., 2006). Adequate supply of plant nutrients at the right time is necessary for hybrids and composite varieties to exhibit their full yield potential (Singh & Kumar, 2016). Plants require nitrogen in larger amounts than other elements as it is a constituent element of protein, nucleic acids, chlorophyll, and many enzymes, and also mediates the utilization of phosphorus, potassium, and other elements (Chapagain and Gurung, 2010). The increased use of nitrogen fertilizer over the past four decades has played a significant role in improving crop yield and increasing agricultural food production worldwide (Barbieri et al., 2008).

However, excess nitrogen can lead to environmental problems such as groundwater contamination through leaching, volatilization, and denitrification (Tamme et al., 2010). By optimizing the application of nitrogen fertilizer, it is possible to reduce soil nitrate leaching (Power et al., 2000). Application of high nitrogen rates may result in poor nitrogen uptake and low nitrogen use efficiency (NUE) due to excessive nitrogen losses (Hammad et al., 2011). Matching application rate and timing with plant demands can improve plant NUE (Liao et al.,2021). However, cereal crops recover only 33% of applied nitrogen on average, with 50-70% of the nitrogen provided to the soil being lost, and NUE may vary with crop species, soil type, and rate of nitrogen fertilizer application (Hawkesford MJ, 2019).Therefore, ideal nitrogen management should optimize yield, farm profit, and NUE while minimizing potential nitrogen leaching beyond the crop rooting zone (Arif et al.,2010).

1.5 Characteristics of Rampur Hybrid-10 and CP 808

Rampur Hybrid-10: It is a national hybrid (F1) seed produced by National Maize Research Program, Rampur, Chitwan registered and certified in 2076 BS. This hybrid maize can be grown with in the altitude of 800-1800 masl and potential yield is around 8-8.5-ton ha^{-1}. It takes 120 days in spring and 150 days in winter for maturity. The special features of Rampur hybrid-10 are: Tolerance to high temp. plant remain green after maturity so maturity for fodder.

CP 808: It is multinational hybrid (F1) seed imported from India registered in 2068 BS and has the average productivity of 9-10 ton ha^{-1} with the average maturity of 120-150 days. Special features: big ear, high yield etc. it can be cultivated in the terai to mid hills of Nepal.

1.6 Effect of Different Nitrogen Levels on Growth and Yield Performance of Hybrid Maize

According to a study nitrogen rates have the most significant impact on the variability of maize yield, accounting for 72.03% of the variability. Nitrogen deficiency can result in a more significant reduction in corm yield compared to the deficiency of other elements by (Nemati and Seyed, 2012). Nitrogen-limiting conditions can hinder plant development by delaying silking, decreasing pre-anthesis crop growth rate, reducing leaf area index during flowering, and accelerating leaf senescence rates throughout the plant's life cycle (Ye, 2022).On the other hand, optimum nitrogen levels can increase growth rate, delay senescence, promote higher leaf expansion rate and duration, and result in higher dry matter production in maize, as observed by (Yue, 2021; Anas et al., 2020) .Maize grain yield is linked to both higher nitrogen uptake and higher ability to utilize nitrogen accumulated in the plant in maize production (Adhikary et al., 2020). The application of nitrogen at higher rates resulted in an increase in both the yield and yield components of maize (Hussain et al., 2007, Bakht et al., 2006 and Khaliq et al., 2009). According to studies conducted by there was a significant increase in the number of grains per cob, 100 seed weight, and grain weight per cob when the nitrogen application rate was increased up to 180 kg N-1 ha. Moreover, the grain yield per plant increased significantly up to 240 kg N ha. In studies conducted by it was found that the highest values for plant height, leaf area index (LAI), and dry matter accumulation were observed when 120 kg N ha-1 was applied (Sagwal and Scholar, 2020; Amanullah et al., 2016; Sharma et al., 2019; Adhikari et al., 2021). The application of 200 kg N ha-1 resulted in the highest recorded values for maximum days to 50% tasseling and 50% silking, number of leaves per plant, number of cobs per plant, number of grains per cob, plant height, as well as grain and biological yield (Bakht et al., 2006). According to the nitrogen requirement for maize can range from 150-240 kg N depending on the variety (Adhikary et al., 2020). The study also found that the highest grain yield of 9352 kg/ha was achieved with the application of 120 kg N ha-1. On the other hand, Ma B, 2022 reported significantly higher grain yield with the application of 180 kg N ha-1. also reported that application of 200 Kg N ha^{-1} increased grain yield of maize (Sharma et al., 2019). The research conducted by Sharma et al., 2019 found that highest 1000 grain weight (482.16g) was obtained from application of 180 kg N and the plant population of 66,666 plants ha. In the same study highest grain yield of l1.10-ton ha was recorded with l180 kg N ha and the plant population of 83,383 plants ha^{-1}. Increasing the nitrogen levels resulted in an increase in the number of cobs per plant, cob length, cob diameter, number of grain rows per cob, number of grains per grain row, number of grains per cob, and thousand grain weight (Adhikary et al., 2020).

1.7 Objective of the Study

The broad objective of this study is to increase the yield of maize in Lamjung, Sundar bazar and regions with similar altitude and climate, by identifying the optimal combination of nitrogen level and maize hybrid variety for maximum growth, yield, and nitrogen use efficiency. The specific objectives of this study are to:

I. Evaluate the impact of varying nitrogen levels on growth and yield parameters of hybrid maize varieties.

II. Determine the optimal nitrogen level for achieving maximum growth and yield of hybrid maize varieties.

III. Compare the performance of different hybrid maize varieties under different levels of nitrogen application.

IV. Provide evidence-based recommendations to maize farmers in Sundar bazar, Lamjung, and mid-hills of Nepal with similar altitude and climatic conditions on the most effective combination of hybrid maize variety and nitrogen level for optimal maize production.

2. Materials and Methods

2.1 Description of Research Site

The experiment was conducted in agronomy farm of Lamjung campus, Sundar bazar, western mid-hills of Nepal lie at the Northern longitude of 28.13^0 Eastern latitude of 84.42^0 with an altitude of 800 masl with subtropical humid climate. The experiment was conducted from 26th March 2022.The average annual rainfall of experimental site is 2000mm. The maximum temperature of experimental site up to 39^0 c at the month of April-June and minimum temperature of 6-10^{0}c at month of December-January. The characteristics of soil used for experiment were:

Table 1: Edaphic Condition of Soil Before the Research Conducted

Coordinates:	84.417 0N, 28.128 0 E
Parent Soil:	Fluvial non calcareous
pH value:	5.88
Organic Matter:	2.00%
Total Nitrogen:	0.10%
Available Potassium (K2O):	152.04 kg/ha
Available Phosphorus (P2O5):	8.051 kg/ha

2.2 Experimental Details

Experiment was conducted in factorial RCBD design. Two mostly cultivated hybrid maize varieties (Rampur Hybrid-10 and CP-808) were used with six different doses of nitrogen levels. There were altogether 36 plots each of 3.6 m^2. Spacing between the adjacent plot was 0.5 m with plant to plant-to-plant distance of 20 cm and row to row of 60 cm. so, that altogether there were 30 plants in each plot. 5 sample plants were taken randomly from each plot excluding the border plants.

Table 2: Table Showing Experimental Details

Experimental detail	Descriptions
Crop	Maize
Variety	Rampur Hybrid-10(V1) and CP-808(V2)
Number of treatments	12
Number of replications	3
Design	Factorial RCBD
Gross plot size	3.6 m2
Net plot size	270m2
Spacing (r*p)	60cm*20cm
Doses of fertilizer	N (0, 120, 150, 180, 210, 240 kg h-1), P (60 kg h-1), and K (40 kg h-1), FYM (10ton ha-1)

Table 3: Table Showing Treatment Details

Treatment combinations	**Treatments (NPK kg h-1 + Varieties)**
V1D0	Rampur Hybrid-10 + 0:60:40
V1D1	Rampur Hybrid-10 + 120:60:40
V1D2	Rampur Hybrid-10 + 150:60:40
V1D3	Rampur Hybrid-10 + 180:60:40
V1D4	Rampur Hybrid-10 + 210:60:40
V1D5	Rampur Hybrid-10 + 240:60:40
V2D0	CP-808 + 0:60:40
V2D1	CP-808 + 120:60:40
V2D2	CP-808 + 150:60:40
V2D3	CP-808 + 180:60:40
V2D4	CP-808 + 210:60:40
V2D5	CP-808 + 240:60:40

2.3 Cultivation Practices

The land was ploughed thoroughly using power tiller 2-3 times to make soil pulverized and leveled. And well decomposed FYM incorporated thoroughly. After 15 days, field layout was done making 36 plots using tape, pegs, rope prior to sowing. Field was treated with Cartap hydrochloride 4% granules, as the field around were infected with cutworm. The recommended dose of FYM @ 10 ton/ ha was applied 15 days before sowing of seeds. The recommended dose of 60 kg P2O5/ha and 40 kg K2O/ha was applied as basal in all plots at the time of seed sowing. 1/2 dose of N (120/150/180/210/240 kg ha^{-1}) was used at the time of seed sowing as basal dose. The remaining 1/2 dose of N was side-dressed at knee high stage and tasseling stage. Bold and disease-free seeds of Rampur Hybrid-10 and CP. The depth of sowing was 3-5 cm. Thinning was done 2 weeks after sowing. At knee high stage some of the plants were damaged by fall army worm, Emmamectin benzoate 5% soluble granule was used to control their damage. First hand weeding was done at the time of application of first split dose of nitrogen and second at the time of tasseling. Along with weeding, soil loosening and earthing up was also done at tasseling stage. When the plants turned yellow and ear husk turned brownish black maize was harvested manually. The harvesting was done from very bottom of plants with sickles. Plants were allowed for sun drying for 2-3 days.

2.4 Data Collection

Required data were taken from tagged plants 5 form each plot. Days to tasseling and silking were recorded from the date of sowing till when 80% plants in each plot produce fully opened tassels and silking start. Data of number of leaves, plant height, stem diameter was co from sampled plant of each plot at maturity stage. And average was calculated from 5 plants. Leaf area was calculated by multiplying leaf length, maximum leaf width and with a correction factor of 0.75 as suggested by Francis et al., 1969. It was taken from 5 tagged plant from each plot at the time of maturity. Length of cob of tagged plants were measured from base to top grain bearing portion of each ear. The average of 5 ears was calculated and expressed as ear length (cm). Diameter of cob was measured with the help of vernier caliper from three parts as top, mid and base and average diameter was calculated for each cob (mm). Weight of cob was measured with the help of weighing machine (gm). After few days of sun drying, the weight of plants with cob were weighed as net plot area (kg/ha) and later converted into ton/ha. Total number of grains per cob was counted from cobs of selected plants of each plot mean was analyzed. A total of 1000 grains were counted and weighed with the help of portable electronic balance. The moisture percentage of grain was determined with the help of gravimetric method. The grain yield per hectare was computed for each treatment from the net plot yields. The moisture percentage of the grain was determined by using gravimetric method. The final grain yield was adjusted to 15% moisture level. Stover yield was calculated by subtracting the cob weight from the total biomass yield. Harvest index (HI) was computed as suggested by Stern,1986.

2.5 Data Analysis

After completion of data collection, data were tabulated according to replications and treatments. Data entry and tabulation was done by using MS-Excel-2019-word processing by MS-Word-2019. Statistical analysis was done by using R-studio version 4.2.2.

3. Results and Discussion

3.1 Growth Parameters

Table 4: Effect of Different Nitrogen Levels on Growth Parameters of Hybrid Maize Varieties

Treatment	Plant height (cm)	No. of Leaves	Leaf Area Index	Stem diameter (mm)
Varieties				
Rampur Hybrid-10	152.05^{a}	12.616^{a}	7.256^{b}	22.33^{a}
CP-808	146.71^{a}	12.467^{a}	7.977^{a}	22.76^{a}
LSD (0.05)	9.32	0.37	0.700	1.01
F test (α=0.05)	NS	NS	*	NS
N levels (kg ha^{-1})				
240	163.71^{a}	12.96^{a}	8.83^{a}	24.60^{a}
210	150.90^{ab}	12.73^{ab}	7.76^{ab}	22.87^{ab}
180	156.75^{ab}	12.67^{ab}	8.46^{a}	23.54^{a}
150	152.07^{ab}	12.80^{ab}	7.89^{ab}	23.26^{a}
120	142.31^{bc}	12.16^{bc}	6.89^{bc}	21.18^{bc}
0	130.53^{c}	11.91^{c}	5.83^{c}	19.83^{c}
LSD(α=0.05)	16.15	0.64	1.21	1.75
CV	9.03	4.28	13.3	6.49
F test	**	*	***	***
Grand mean	149.38	12.54	7.61	22.55

*Note: CV: coefficient of variation, LSD: Least significant differences, '***' significant at 0.1%, '**' significant at 1%, '*' significant at 5%, 'NS' non-significant, N: Nitrogen levels.*

3.1.1 Plant Height

Plant height at 90 DAS was found statistically significant due to various levels of nitrogen. While there were no significant changes observed due to different varieties on plant height at 90 DAS. The maximum plant height was found in the plot with 240 kg N ha^{1}(163.72 cm) followed by 180 kg N ha^{-1} (156.76 cm). whereas the minimum plant height was found in control plot (130.54 cm) and the plot with 120 kg N ha^{-1}(142.32cm). plant height at 150 kg N ha^{-1} was statistically at par with 180 and 210 kg N ha^{-1}.

Increasing the amount of N application leads to several positive effects on plant growth, such as enhanced cell division, elongation, and nucleus formation, which promote the development of green foliage and an increase in chlorophyll content. As a result, the rate of photosynthesis is boosted, and the stem grows longer, ultimately leading to an overall increase in plant height (Diallo *et al*.,1996, Thakur et al., 1998). These findings were in similar to the finding of Adhikary et al., 2020 , the maximum plant height (199.92 cm) with the application of 220 kg N ha-1 . Studies conducted by Dawadi and Sah (2012), Bakht et al. (2006), Khan et al. (2014), and Sagwal and Scholar (2020) all showed that an increase in nitrogen level led to an increase in plant height of hybrid maize varieties. This relationship between nitrogen and plant height can be explained by improved vegetative growth, which promotes mutual shading and internodal extension.

3.1.2 Number of Leaves

There was no significant difference in number of leaves due to different varieties, but with increasing level of nitrogen there is increasing in number of leaves. Highest number of leaves were obtained at 240 kg N ha^{-1} (12.96) which was at statistically at par with Number of leaves at 180, 210, 150 kg N ha^{-1} respectively and lowest leaves number were obtained in control plot.

3.1.3 Stem Diameter

There was no significant difference was obtained due to different varieties. Stem diameter was found to be influenced by varying level nitrogen. Stem diameter at 240 kg N ha^{-1} (24.60 mm) was statistically at par with 180 and 150 kg N ha^{-1} and lowest cob diameter was found in control plot (19.83 mm). (Hassan et al., 2010) also found similar type of result.

3.1.4 Leaf Area Index (LAI)

LAI was found statistically significant on both the varieties and nitrogen level. The effect of different varieties and nitrogen levels on LAI was highly significant. CP-808 produced the higher LAI (7.977) as compared to Rampur hybrid-10 LAI (7.256). The highest nitrogen level (240 kg N ha^{-1}) produced maximum LAI (8.838) which was statistically at par with 180 kg N ha^{-1} (8.464) followed by 210 kg N ha^{-1} (7.769) and 150 kg N ha^{-1} (7.899) respectively. The lowest LAI was found in control plot (5.834) and plot with 120 kg N ha^{-1} (7.899). There was no significant effect of varieties and nitrogen levels interaction on LAI of maize.

Highest LAI in CP-808 as compared to Rampur hybrid-10 may be due to difference in leaf arrangement, chlorophyll content and activities of photosynthetic enzymes as affected by genetic characteristics of individual maize varieties. plant height reflects the canopy of plant. Increase in leaf area index may be due to rapid cell division and active cell multiplication

brought up by nitrogen. (Hammad et al., 2011) found the highest LAI at 250 kg N ha^{-1} (5.06) followed by 200 kg ha^{-1} (4.74) respectively.

3.2 Yield parameters

Table 5: Effect of Different Nitrogen Levels on Yield Parameters of Hybrid Maize Varieties.

Treatment	Cob length (cm)	Cob diameter (mm)	Cob Weight	Grain/cob
Varieties				
Rampur Hybrid-10	15.82b	40.61b	11.09a	322.16b
CP-808	16.59a	42.02a	11.35a	396.92a
LSD (0.05)	0.72	1.39	0.69	58.24
F test	*	*	NS	*
N levels (kg ha-1)				
240	18.05a	45.59a	14.84a	451.60a
210	16.61bc	42.84bc	11.78ab	378.90ab
180	17.09ab	44.63ab	13.10ab	415.60ab
150	16.05bc	41.52c	10.65b	341.26bc
120	15.41c	38.28d	10.42b	331.16bc
0	14.03d	35.05e	6.54c	238.73c
LSD(α=0.05)	1.25	2.42	3.41	1.25
CV	6.44	4.89	24.05	23.43
F test (α=0.001)	***	***	**	**
Grand mean	16.21	41.32	11.2	359.54

*Note: CV: coefficient of variation, LSD: Least significant differences, '***' significant at 0.1%, '**' significant at 1%, '*' significant at 5%, 'NS' non-significant, N: Nitrogen levels.*

Table 5: Effect of Different Nitrogen Levels on Yield Parameters of Hybrid Maize Varieties.

Treatment	Test weight (gm)	Biological yield	Grain yield	Harvest index	Stover yield
Varieties					
Rampur Hybrid-10	228.41b	36.45a	7.46a	14.50b	25.36a
CP-808	249.77a	36.46a	7.99a	15.68a	25.10a
LSD (0.05)	18.922	4.282	0.89	0.69	2.59
F test	*	NS	NS	**	NS
N levels (kg ha-1)					
240	269.30a	43.96a	10.40a	17.80a	29.12a
210	252.01ab	38.26ab	7.93bc	15.02b	26.47a
180	252.18ab	41.60ab	9.29 ab	16.62a	28.50a
150	233.11bc	35.59b	7.16c	14.17b	24.94a
120	221.69bc	35.47b	6.56c	12.77c	25.05a
0	206.25c	23.86c	5.01d	14.11b	17.31b
LSD(α=0.05)	32.77	7.41	1.55		4.42
CV	11.44	16.99	16.75	6.69	14.89
F test (α=0.001)	**	***	***	***	***
Grand mean	239.09	36.45	7.73	15.09	25.23

*Note: CV: coefficient of variation, LSD: Least significant differences, '***' significant at 0.1%, '**' significant at 1%, '*' significant at 5%, 'NS' non-significant, N: Nitrogen levels.*

3.2.1 Cob Length

CP-808 produced the highest cob length of 16.598 cm and shortest by Rampur hybrid-10 of 15.821cm. The length of cob was found to be influenced by both the varieties and nitrogen levels. Statistical analysis of the data showed that the various levels of nitrogen had significant effect on cob length. The plot with highest level of nitrogen 240 kg N ha^{-1} produced 18.05 cm of cob followed by 180 kg N ha^{-1} (17.09 cm). cob length at 210 kg N ha^{-1} (16.61 cm) was statistically at par with 150 kg N ha^{-1} (16.05 cm). control plot had the least cob length of 14.03 cm.

Derby et al., 2004 reported that the increased length of the ear could be attributed to the favorable solar light environment, which led to higher assimilation and subsequent conversion to starches. The results are also in agreement with (Turgut, 2000), who reported increase in nitrogen levels positively influences the cob length of maize. Similar type of result was found by (Ahmad et al., 2018), in which cob length at 180 kg N ha^{-1} (17.18 cm) followed by 150 kg N ha^{-1} (16.52 cm).

3.2.2 Cob Diameter

Both varieties and nitrogen levels showed the statistically significant result for cob diameter. CP 808 had highest cob diameter 42.022 mm as compared to Rampur hybrid-10 (40.61 mm). plot with nitrogen level 240 kg ha^{-1} produced the highest cob diameter of 45.59 mm followed by 44.63 mm (180 kg N ha^{-1}) and 42.84 mm (210 kg N ha^{-1}) respectively. Control plot had the least cob diameter of 35.05 mm.

A similar type of result was obtained by (Adhikari et al., 2021), who observed the highest cob diameter with the application of 220 kg N ha^{-1} (45.40 mm). The increment of cob diameter could be due to the supply of sufficient nitrogen. A higher cob diameter was obtained from higher dose of Nitrogen application due to sufficient availability of Nitrogen which is responsible for cell division and cell elongation.

3.2.3 Cob Weight

There was no significant difference in cob weight due to different varieties but at different nitrogen levels there was variance in cob weight was found. Highest cob weight was found at 240 kg N ha^{-1} (14.84-ton ha^{-1}) and was statistically at par with 180 and 210 kg N ha^{-1}. The lowest cob weight per hectare was found in control plot (6.54-ton ha^{-1}).

3.2.4 Grain Per Cob

Analysis of data revealed that the different varieties and various levels of nitrogen had significantly ($p \leq 0.5$ and $p \leq 0.01$ respectively) affected the number of grains per cob. CP 808 produced the maximum grains per cob i.e., 396.92 as compared to Rampur hybrid-10 (322.16). Maximum number of grains per cob was obtained from the plot with 240 kg N ha^{-1} (451.60) and 180 kg N ha^{-1} (415.60) which was statistically at par with 210 kg N ha^{-1} (378.90). And the plot with 150 kg N ha^{-1} produced the grains number which were statistically at par with 180 kg N ha^{-1} as shown in table. The control plot produced the cob with least cob grain number (238.73).

The findings align with those reported indicating that increasing nitrogen levels can result in higher grain yields per cob by (Adhikari et al., 2021; Dawadi and Sah, 2012). The increase in the number of grains per cob under higher nitrogen levels can be attributed to reduced competition for nutrients, which enables plants to accumulate more biomass, have a higher capacity to convert more photosynthesis into sink, and ultimately produce more grains per cob. The optimal nitrogen fertilizer availability helped the plant to utilize nutrients to their maximum potential, resulting in a higher number of grains per cob. The number of grains per cob is a critical factor in determining the final grain yield.

3.2.5 Test Weight

Statistical analysis of the data revealed that, both the different varieties and various level nitrogen levels significantly affected the test weight (1000 grains weight). CP 808 had the highest test weight (249.77 gm) as compared to Rampur hybrid-10. And highest test weight was found in the plot with 240 kg N ha-1 (269.30 gm) and was statistically at par with 180 (252.18 gm) and 210 kg N ha-1 (252.01 gm) respectively and lowest test weight was found in control plot (206.25 gm).

Highest 1000 grains test was also obtained in where 254.1 gm of 1000 grains at 160 kg N ha-1. In (Adhikari et al., 2021), 220 kg N ha-1 yield highest test weight (276.77gm). also found similar result in higher dose of nitrogen (Arif et al., 2010; Hussain et al., 2007; Ahmad et al.,

2018).

3.2.6 Stover Yield

Statistical analysis of the data revealed that various levels of nitrogen had significantly affected on stover yield ($p \leq 0.001$). Maximum stover yield was found in 240 kg N ha^{-1} (29.12-ton ha^{-1}) which was statistically at par with 180 kg (28.50-ton ha^{-1}) and 210 kg (26.47-ton ha^{-1}) and lowest stover yield was found in control one (17.31-ton ha^{-1}).

Similar type of result was obtained who found highest stover yield in highest dose 220 kg N ha^{-1} (12.91-ton ha^{-1}). (Bhandari et al., 2019) also found highest stover yield in 200 kg N ha^{-1}(10.61-ton ha^{-1}) by (Adhikari et al., 2021). As a also found the highest stover yield in highest dose of nitrogen fertilizer (Krishnamurthy et al., 1974; Bhatti and Gurmani, 2007).

3.2.7 Biological yield

Significant difference ($p \leq 0.001$) in biological yield was found due to varying levels of nitrogen but not due to different varieties. Maximum value was obtained in the plot with 240 kg N ha^{-1} (43.96-ton ha^{-1}) followed by 180 kg N ha^{-1} (41.60-ton ha^{-1}) and this was statistically at par with 210 kg N ha^{-1} (38.26-ton ha^{-1}) and lowest biological yield was found in control plot (23.86-ton ha^{-1}). Hammad et al., 2011 found 16.56-ton ha^{-1} of biological yield in 300 kg N ha^{-1} and also found highest biological yield in higher dose of nitrogen (Bahadar Marwat et al., 2009). Nitrogen application rate showed highly significant effect on biological yield as well as its response was linear and highly significant.

3.2.8 Grain Yield

Statistical analysis of data uncovered that the effect of varieties had no significant effect on grain yield but different levels of Nitrogen had a significant effect on grain yield. Various levels of nitrogen had significantly ($p \leq 0.001$) affected the grain yield. Highest grain yield was obtained from the plot with 240 kg N ha^{-1} (10.40 ton ha^{-1}) followed by 180 kg N ha^{-1} (9.295 ton ha^{-1}) and 210 kg N ha^{-1} (7.93 ton ha^{-1}) respectively. The control plot produced the least grain yield of 5.01 ton ha^{-1}.

Similar type of result was obtained who found that application of high doses of nitrogen at 220 kg ha^{-1} produced highest yield of 10.07 ton ha^{-1}. Higher levels of nitrogen may result in increased grain yield due to reduced competition for nutrients by (Adhikari et al., 2021; Sharma et al., 2019). This, in turn, leads to a larger plant canopy and increased photosynthetic activity, resulting in the accumulation of more biomass and ultimately yielding bold grains.

3.2.9 Harvest Index

Highest HI was found at 240 kg N ha^{-1} (17.80%) which was statistically similar to that plot with 180 kg N ha^{-1} (16.62%). HI at 210 kg N ha^{-1} was statistically at par with 150 kg N ha^{-1}, and 120 kg N ha^{-1}. And CP 808 (15.68%) had the highest HI as compared to Rampur hybrid-10 (14.50%). Our result was satisfied with those of in which highest HI was found in 220 kg N ha^{-1} (43.38-ton ha^{-1}) (Adhikari et al., 2021). At low N supply, crop growth rate slows down causing reproductive structures to decline, as a result lower maize grain yield (and its components) as well as lesser harvest index (Hammad et al., 2011).

4. Summary and Conlusion

In conclusion, this study aimed to determine the best combination of nitrogen levels and hybrid maize varieties for optimal growth and yield in Sundar bazar municipality, Lamjung, Nepal. It was concluded that increasing nitrogen levels significantly enhanced the growth and yield parameters of hybrid maize varieties. The application of 240 kg N ha-1 resulted in the highest values for plant height, number of leaves, leaf area index (LAI), stem diameter, thousand grain test weight, grain per cob, grain yield, biological yield, and harvest index. Furthermore, the hybrid maize variety CP 808 exhibited superior performance compared to Rampur Hybrid-10 in terms of grain yield, thousand grain test weight, cob length, grain per cob, and LAI. These findings have important implications for maize farmers in Sundar bazar, Lamjung, and mid-hills of Nepal with similar altitude and climatic conditions. By cultivating hybrid maize variety CP-808 with the application of 240 kg N ha-1, farmers can increase their yields and income and contribute to the ever-increasing demand of maize feed (poulry and cattle feed) and food. However, further research on multilocation and multi-season basis is needed to consolidate the findings retrieved from the study.

This research also presents opportunities for academia and policy makers to address the challenges facing maize production in Nepal based on the research gaps and opportunities pointed out by this study. The low yield potential of existing genotypes can be addressed by cultivating new high-yielding varieties using optimal cultural practices and timely application of appropriate nutrients in the required amounts. Furthermore, this study underscores the importance of improving access to improved seeds and quality fertilizers to enhance maize productivity. By addressing the challenges and seizing the opportunities presented by this research, it is possible to improve maize production and contribute to food security in hilly Nepal.

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